MICROFOSSILS FROM PLEISTOCENE TO RECENT DEPOSITS, LAKE EYRE, SOUTH AUSTRALIA.

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I. SUMMARY

Samples from sands, clays and limestones on the south-eastern corner of Lake Eyre were found to contain remains of fresh or brackish water microscopic plants and animals which inhabit inland and coastal lagoons, together with species of brackish water foraminifera. Deposition probably took place during Pleistocene high sea levels.

II. INTRODUCTION

Samples from two shallow boreholes sunk with a post-hole digger on the south-eastern corner of Lake Eyre and from a thick shell bed 36 feet above the present level of the lake were submitted for routine micropalaeontological examination by Mr. D. King, Geologist, South Australian Department of Mines, who was a member of the party led by Mr. Warren Bonython to Lake Eyre North, 400 miles north of Adelaide in May, 1953. The object of the expedition was to investigate further the geography and geology of the lake and the occurrence of native sulphur observed on the lake shore in December, 1951, after the flooding in 1949-50.

Bore No. 1 situated on the flat between dunes, Arbitrary Reduced Level of surface 110·75 ft., passed through the following strata:

0ft. 0in. to 0ft. 6in.: Yellow-brown, very fine, slightly clayey quartz sand with grit. Residue after washing consists of subangular quartz grains usually etched and pitted on the surface, some large grains of opaline silica and an occasional oolite of calcite.

0ft. 6in. to 2ft. 4in.: Fine yellow-brown quartz sand, similar to that at the surface.

2ft. 4in. to 4ft. 6in.: Yellow-brown fine clayey sand, washed residue of subangular quartz grains with a little oolitic calcite.

4ft. 6in. to 6ft. 6in.: Yellow-brown fine clayey sand, washed residue of subangular quartz grains of varying size with well-rounded grains of cryptocrystalline silica.

6ft. 6in. to 7ft. 9in.: Pale yellow-brown coarse to gritty sand with some gypsum; washed residue mainly of quartz grains of varying size and some gypsum fragments.

7ft. 9in. to 10ft. 3in.: Brown clay with fine and crystalline gypsum and quartz grit; washed residue of quartz grains of varying size with both seed and crystalline gypsum.

10ft. 3in. to 12ft. 10in.: Fine gypseous sand and clay; washed residue of large subrounded quartz grains much etched on the surface.

12ft. 10in. to 16ft. 4in.: Light brown sandy clay; washed residue of coarse quartz grains, many of them rather flat and of even size, and some gypsum crystals.

16ft. 4in. to 18ft. 8in.: Banded vari-coloured plastic clay; washed residue similar to the previous.

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18ft. 8in. to 21ft. 4in.: Fine gravel with white limestone fragments; the coarse fraction of the washed residue consists of large quartz grains finely etched on the surface, and fragments of porcellanite and limestone.

21ft. 4in. to 22ft. 0in.: Black clay; the finer fraction (passing through 20 mesh) of the washed residue consists of subangular quartz grains with some limestone fragments. Also present are a number of platy grains of saponite with laminar intergrowths of finely divided pyrite.

22ft. 0in. to 22ft. 5 in.: Hard white dolomitic limestone with a gastropod mould. Such friable material as could be washed free of clay yielded white limestone fragments, subangular quartz grains some of them flat, and plates of pyrite crystals.

Bore No. 4.—Situated half mile south-east of Prescott Point at the north of Sulphur Peninsula, passed through:

0ft. to 2ft. 3in.: Pale brown clayey sand; washed residue of medium fairly even-sized subangular quartz grains with some limestone fragments.

2ft. 3in. to 3ft. 6in.: Grey sandy clay; washed residue of fine angular and subangular quartz grains, some so little worn as to still retain their crystalline form.

3ft. 6in. to 12ft. 0in.: Brown clay; washed residue of angular quartz grains, some very fresh, and an occasional grain of pyrite.

12ft. 0in. to 16ft. 10in.: Blue, very sticky clay; washed residue of medium-sized subangular quartz grains and calcite fragments, with authigenic pyrite some of which is intergrown with saponite.

16ft. 10in. to 17ft. 0in.: Hard white limestone, the friable portion of which was washed, leaving a residue of medium-sized subangular quartz grains, white calcite fragments and a pale green mineral of the beidellite-nontronite series, held together by calcite.

Without exception, the samples were fossiliferous, almost all having oogonia of *Chara* and relatively fewer heavily calcified valves of ostracoda and tests of "*Rotalia*" *beccarii*. The distribution of the organisms is shown in tabulated form at the end of the paper. The sands and sandy clays in Borehole 1 from the surface to 16ft. 4in. apparently represent the most favourable environment for their development; it is suggested that these represent a period of increasing salinity in the lake.

Two other samples were examined for identifiable microfossils with negative results:

1. Grey clay interstratified with limestone from Position B, point at small island with sand spit.

   Very little residue remained after washing, and this consisted mainly of flat, worn grains of calcite with some angular quartz grains.

2. Dense white clayey limestone taken from 3ft. 6in. to 4ft. 6in. in a bore at Locality C.

The only organic remains are horny tubes of unidentified origin. The most interesting sample was taken at position M from the upper shell bed, consisting almost entirely of shells of *Coxiella gilesi* (Angas). The unconsolidated matrix was found to contain numerous valves of two species of ostracoda and thin-shelled, well-preserved tests of a form of "*Rotalia*" *beccarii*, together with a small number of oogonia of *Chara*. One broken fragment of the pelecypod *Corbiculina*, not specifically identifiable, was found, and some indeterminate fish vertebrae.

III. ENVIRONMENT

Regional investigations have not yet reached the stage where it is possible to determine whether conditions of sedimentation were lacustrine or estuarine. Since my preliminary note (Ludbrook, 1953) was published Dr. R. W. Fairbridge has suggested to me that the microfaunal assemblage is one which would naturally inhabit an extensive gulf or estuary reaching Lake Eyre via Lake Torrens from the head of Spencer's Gulf during the high sea level phases of the Pleistocene. While this is certainly feasible, freshwater lake deposits now represented by indurated oolitic ostracode limestones, similar to the dolomitic limestone in which the borings ceased, have been found in widely separated localities in the west of South Australia. Whether the lacustrine environment persisted at Lake Eyre, increasing salinity providing a favourable milieu for brackish water organisms which had been introduced by birds, or whether freshwater lakes were transformed during part of the Pleistocene into the estuary suggested by Dr. Fairbridge can be determined only by observations made on a regional scale.*

IV. ACKNOWLEDGMENTS

I am indebted to the Petrology Section, Department of Mines, for identification of the saponite and beidellite-nontronite minerals, to Dr. H. B. S. Womersley for placing specimens of *Characeae* belonging to the Botany Department, University of Adelaide, at my disposal, to Mr. B. C. Cotton for allowing me to examine mollusca in the South Australian Museum, and to Dr. Rhodes Fairbridge for drawing my attention to the possible conditions of deposition

V. FAUNA

FORAMINIFERA

Family NONIONIDAE.

Genus ELPHIDIUM Montfort, 1808.

Type species *Nautilus macellus* Fichtel & Moll.

(?) **Elphidium advenum** (Cushman).

pl. 1, fig. 9

For early synonymy see Cushman, 1939, U.S.G.S. Prof. Paper 191, p. 60; Bermudez, 1949, Cush. Lab. Foram. Res. Spec. Pub., **25**, p. 167.

Elphidium advenum (Cushman), 1944, Cushman Lab. Foram. Resp. Spec. Pub., **12**, p. 26, pl. 3, fig. 36.

Elphidium advenum (Cushman) Howchin & Parr, 1938, Trans. Roy. Soc. S. Aust., **62** (2), p. 299.

Elphidium advenum Cushman, Parr, 1943, Mal. Soc. S. Aust. Pub. **3**, p. 20; 1950, Journ. Roy. Soc. W. Aust., **34**, p. 72.

Material—One worn specimen, sample F173/53 Bore 1, 0ft. 0in.-0ft. 6in.

The calcified condition of the single specimen renders identification very doubtful. Its occurrence only in the surface sample of Bore 1 suggests that the species may have been introduced by birds and had no continuous existence in the area. On the other hand, it is recorded as occurring frequently in the late Pleistocene "*Arca*" horizon of Peppermint Grove (Parr, 1950).

* Since the above was submitted for publication, Mr. V. R. Rao has shown me a paper by Jacob, Sastry and Sastri on the Microfossils of the Impure Gypsum from the Jamsar Mine, Bikaner, published in the Proceedings of the Symposium on the Rajputana Desert (Bulletin of the National Institute of Sciences of India 1, September, 1952). The authors record (p. 68) the occurrence of "*Chara*, Ostracoda and a few small shallow water marine Foraminifera in the Intertrappean beds of Rajahmundry" which they believe to be of Eocene age, and attribute the presence of *Chara* to its being transported from fresh-water areas. In a supplementary note (p. 69) they record the discovery of the foraminifer *Discorbis*, probably blown in by the wind, with shells of *Vivipara bengalensis* (Lam.) and *Chara* "fruits" in gypsum deposits at Siasar.

Recently, an assemblage identical, except for minor specific differences, to that in the Lake Eyre clays has been recovered from surface silty sands in swamps bordering Lake Alexandrina. Here also *Chara* is associated with *Coxiella*, ostracodes, "*Rotalia*" *beccarii* var. *tepida* and *Elphidium advenum*.

Howchin (1901, p. 9) postulated dispersal by birds of the two species of *Elphidium* which he discovered in the silt at Yorketown Lagoon.*

Genus NONION Montfort, 1808.

Type species *Nautilus incrassatus* Fichtel & Moll.

(?) **Nonion scapha** (Fichtel & Moll)

pl. 1, fig. 10.

For synonymy see Cushman, 1939, U.S.G.S. Prof. Paper, **191**, p. 20.
Nonion scapha Fichtel & Moll. Parr, 1943, Mal. Soc. S. Aust. Pub. **2**, p. 20.
Nonion scaphum (Fichtel & Moll). Cushman, 1946, Cush. Lab. Foram. Res. Spec. Pub., **17**, p. 14.

One specimen, sample F177/53.

Bore 1. 6ft. 6in.-7ft. 9in.

As the test is coated with thin calcite and the aperture obscured, identification of this species is tentative only.

Family ANOMALINIDAE

Genus CIBICIDES Montfort, 1808.

Type species *Cibicides refulgens* Montfort.

Cibicides refulgens Montfort

pl. 1, figs. 11, 12.

For early synonymy see Cushman, 1931. U.S. Nat. Mus. Bull., **104**, pt. 8, p. 116, *Cibicides refulgens* Montfort, Cushman & Todd, 1945, Cush. Lab. Foram. Res. Spec. Pub., **15**, p. 70. Cushman & Gray, 1946, *id.* Spec. Pub., **19**, p. pl. 8, figs. 15-17, Cushman & Todd, 1947, *id.* Spec. Pub., **21**, p. 23, pl. 4, fig. 7. Chapman & Parr, 1935. Journ. Roy. Soc. S. Aust., **21**, p. 3, Crespin, 1943, Min. Res. Sur. Bull., 9 (Pal. Ser. 4), p. 78 (mimeographed). Parr, 1950, Journ. Roy. Soc. W. Aust., **34**, p. 71.

Material—One specimen, Sample F.

Borehole 4. 3ft. 6in.-12ft. 0in.

The specimen recovered is small and well preserved and typical of the species. Although its occurrence also suggests fortuitous introduction, it was recorded as common in the late Pleistocene "*Arca*" horizon, Peppermint Grove.

Family ROTALIIDAE.

Genus ROTALIA Lamarck, 1804.

Type species *Rotalia trochidiformis* Lamarck.

"**Rotalia**" **beccarii** Linné cf. var. **tepida** Cushman.

pl. 1, figs. 13, 14, 15

Rotalia beccarii (Linné) var. *tepida* Cushman, 1926, Carnegie Inst., Washington, Pub. 344, p. 79, pl. 1. D. K. Palmer, 1945, Bull. Amer. Pal., **29** (115), p. 60 (*fide* Bermudez); Bermudez, 1949, Cush. Lab. Foram. Res. Spec. Pub., **25**, p. 234.
Streblus beccarii (Linné) var. cf. *tepida* (Cushman). Parr, 1950, Journ. Roy. Soc. W. Aust., **34**, p. 22.

Material—Calcified specimens, as many as 49 in one sample, from almost all but 5 samples from Boreholes 1 and 4; numerous (over 100) well-preserved specimens from matrix of upper (*Coxiella*) shell bed.

The occurrence of this species in almost every sample including the sulphur bed suggests that its introduction has not been completely fortuitous. Two possibilities present themselves: the first, that widespread estuarine conditions during the late Pleistocene enabled the species to spread towards Lake Eyre from the head of Spencer's Gulf, the second, that the variety has been introduced by birds or by winds into shallow saline lakes in the late Pleistocene, and finding a favourable habitat rapidly established itself.

* The uppermost eighteen inches of gypseous mud in Peesey's Swamp, Yorke Peninsula, carries a brackish-water microfauna dominated by *Elphidium advenum* in association with the gastropoda *Coxiella confusa* Smith, *Batillaria* (*Batillariella*) *estuarina* (Tate) and ostracodes. This fauna is distinct from that of the underlying travertine-capped, loosely consolidated Recent shelly sandstone and limestone which carries abundant marine littoral mollusca and foraminifera.

All specimens show abundant evidence of environmental influence. As compared with marine examples of the species, the tests are small and variable in shape. Those recovered from the clays of Borehole 1 and Borehole 4 are all heavily calcified. Very few showed the umbilical plug generally characteristic of the species.

All the Lake Eyre specimens appear, so far as one can determine in the absence of authentic topotypes for comparison, to be close to the variety *tepida* described by Cushman (1926, p. 79) from shallow and stagnant water at Porto Rico. It has been recorded and illustrated by Bermudez (1949, p. 234, pl. 15, figs. 49-51) associated with a shallow water molluscan fauna from the Upper Miocene of Las Salinas Formation Dominican Republic and by Parr from the "*Arca*" horizon, Peppermint Grove.

The two specimens figured show the degree of variation presented by the Lake Eyre specimens. One (pl. 1, fig. 15) is typical of the calcified tests obtained from the clays of the bores. The other (pl. 1, figs. 13, 14) is a somewhat extreme example of the form which occurs numerously in the *Coxiella* bed. It is characterized by its small, fairly thin test, only slightly limbate sutures and absence of umbilical plug. The astral lobe, if developed at all, is frequently broken and not preserved.

MOLLUSCA.

Class **PELECYPODA**
Superfamily SPHAEREACEA.
Family CORBICULIDAE.
Genus CORBICULINA Dall, 1903.

Corbiculina Dall, 1903, Proc. Biol. Soc. Washington, **16**, p. 6.

Type species (monotypy) *Corbicula angasi* Prime.

Corbiculina sp. indet.

Material—One broken specimen, sample F172/53.

A fragment only of the hinge portion of a juvenile shell was collected from the upper shell bed. In view of extreme intraspecific variation in this genus, it is impossible to decide whether it is the Recent species *Corbiculina desolata* (Tate) or not.

Class **GASTROPODA**
Superfamily RISSOACEA.
Family ASSIMINEIDAE.
Genus COXIELLA Smith, 1894.

Coxiella Smith, 1894, Proc. Malac. Soc. **1**, p. 98.
(*Blanfordia* Cox, 1868, Mon. Aust. Land Shells, p. 94, *non* Menke.)
(*Coxielladda* Iredale & Whitley, 1938, S. Aust. Nat., **18** (3), p. 66.)
(*Blandfordia* Tate 1894, Trans. Roy. Soc. S. Aust., **18**, p. 196, lapsus calami for *Blanfordia*.)

Type species (monotypy) *Truncatella striatula* Menke.

Coxiella gilesi (Angas).
pl. 1, fig. 1.

Paludinella gilesi Angas, 1877, Proc. Zool. Soc., March, p. 169, pl. 26, fig. 2.
Paludinella gilesii Angas. Tate & Brazier, 1882, Proc. Linn. Soc. N.S.W., **6**, p. 564.
Blandfordia stirlingi Tate, 1894, Trans. Roy. Soc. S. Aust., 18, p. 196
Coxielladda gilesi Iredale & Whitley, 1938, S. Aust. Nat., **18** (3), p. 66.
Coxielladda gilesi Angas. Cotton, 1942, Trans. Roy. Soc. S. Aust., **66** (2), p. 129.

Description—Shell thin, globose-turbinate, perforate, with a rather low spire, apparently orange or flesh-coloured, but almost always bleached white.

Apex subacute, flattened at the origin, protoconch of 1½ flatly convex almost smooth turns constricted at the suture, followed by 4½ roundly convex whorls fairly rapidly increasing in size, arcuate in profile, sculptured with fine, somewhat irregular, transverse growth strial. Sutures impressed, strongly marked. Body whorl large, about three-quarters total height of shell. Umbilicus narrow, generally almost concealed by the expansion of the aperture over the columella.

Aperture subovate, roundly angulate posteriorly and rounded anteriorly, peristome entire, everted over the columella, parietal callus thin and frequently broken.

Dimensions of Figured Specimen—Height 5·3; width 4; height of body whorl 4; height of aperture 3·7; width of aperture 2 mm.

Type Locality—Lake Eyre.

Holotype—British Museum.

Material—Innumerable specimens, upper shell bed, Lake Eyre North.

Distribution—Lake Eyre, Lake Callabonna.

Observations—There is no evidence that this shell has survived desiccation of the area. Although both Angas, who described the Lake Eyre species, and Tate, who described its Lake Callabonna counterpart, found one specimen retaining the original colour, all the specimens seen by the writer have been bleached white.

The species is closely related morphologically and in apparent habitat to *Coxiella confusa* (Smith) found sometimes in enormous numbers in submarginal lagoons and salt lakes in the southern part of the State. The genus is euryhaline, with a very wide range of salinity tolerance covering from freshwater to waters more saline than the sea, its preference apparently being for the latter.

Iredale and Whitley (1938, p. 66) introduced without diagnosis the name *Coxielladda* for *Paludina* (*sic*) *gilesi* Angas. On morphological grounds, it is impossible to select diagnostic generic characters to justify the genus. Intra specific variation in *Coxiella* is considerable, particularly in the height of the spire, and to give this the status of generic diagnosis (Cotton 1942, p. 129) can hardly be supported. Neanic specimens of *Coxiella confusa* bear a very close resemblance to adults of *Coxiella gilesi*.

The species described by Tate (1894, p. 196) as *Blandfordia stirlingi* is almost certainly conspecific with the present species, although only a statistical analysis of the very numerous examples from the two areas can establish the fact. Tate (l.c.p.195) noted the relationship between the southern *Coxiella confusa* (= *Blanfordia striatula* Tate *non* Menke). Increasingly saline conditions in Lake Eyre doubtless provided a favourable milieu for the development of innumerable Coxiellas. In this environment *Pontocypris attenuata* could also survive and "*Rotalia*" *beccarii* although inadequately nourished, maintain a foothold.

The affinities of the genus *Coxiella* are ill-defined. Wenz (1938, p. 582) places it in the Tomichiinae, subfamily of the *Truncatellidae* to which it appears to the writer to be not closely related. It is here placed in the *Assimineidae*; it seems to be close to *Paludinella* in which *gilesi* was originally placed by Angas.

OSTRACODA.

Family CYPRIDAE.

Genus CYPRIS Muller.

Type species *Cypris pubera* Muller.

(?) **Cypris** sp.

pl. 1, figs. 7, 8.

Description—Carapace viewed laterally, broadly reniform, greatest height in the middle, equal to more than half the length. Anterior extremity gently arcuate, proterior extremity flatly rounded; dorsal margin arched, highest in front of the middle ventral margin sinuated in the middle valves unequal, right slightly larger than left and overlapping it in part of the middle of the dorsal margin.

Surface when well preserved sculptures with a fine reticulate pattern. Adductor muscle scars four in the middle of the shell, frequently visible from the outside.

Dimensions—Length 0·6 mm.; width 0·36 mm.

Observations—Although it is generally obscured by a coating of calcite which may be very thick, the reticulate sculpture readily characterizes the species which I have not so far been able to identify.

Genus PONTOCYPRIS G. O. Sars, 1866.

Type species *Pontocypris trigonella* G. O. Sars.

Pontocypris attenuata G. S. Brady.

pl. 3, figs. 5, 6.

Pontocypris attenuata Brady, 1868, Ann. Mag. Nat. Hist., ser **4**, **2**, p. 179, pl. 4, figs. 11-14; Brady, 1880, Chall. Rep. Zool., **1** (3), p. 38, **pl.** 15, figs. 1a-d; Brady, 1890, Trans. Roy. Soc. Edin., **35**, **p.** 491, pl. 1, figs. 3, 4; Chapman, 1902, Journ. Linn. Soc. Lond., **28**, p. 419; Chapman, 1910, *id.*, **30**, p. 427; Chapman, 1919, Austr. Abstract, Exped., Ser. C. **5** (7), p. 17; Chapman, 1941, Trans. Roy. Soc. S. Aust., **65** (2), p. 194, pl. 9, fig. 8.

Material—45 single valves.

Observations—This is a shallow water Indo-Pacific and Australian species which has been recorded twice by Chapman from deep water, first at 1,215 fathoms at Funafuti and secondly from 505 fathoms off South-Eastern Australia. With the exception of one specimen from 16ft. 4in. to 18ft. 8in. in Borehole No. 1, all the present examples were found either in the matrix of the upper shell bed or in the clay beneath the shell bed. This would indicate that the species was of late sporadic introduction and survived only in saline water.

No undamaged pair of valves was obtained. Many of the single valves, both adult and juvenile, one of which is figured (pl. 1, fig. 6) still retained the conspicuous posterior spine which Brady (1890, p. 491) and Chapman (1941, p. 194) have noted. One specimen bears an additional small anterior spine. Either the spines are an inconstant feature, or they are easily broken from the carapace and not preserved.

VI. FLORA

1. Oogonia of Characeae.

Nearly all samples contain oogonia of *Chara* probably belonging to more than one species. These could not be identified as belonging to any described species living in South Australia. The three shapes illustrated (pl. 3, figs. 2, 3, 4) may possibly represent three species.

2. Leaves.

From the matrix of the *Coxiella* shell bed some small, elongate, rather thick leaves, possibly of chenopodiaceous plants were recovered. These had probably been blown in by the wind and deposited with the shells.

VII. DISTRIBUTION

The distribution of the microfossils and the number of specimens recovered from washing about 200 gms. of each sample are shown in the distribution table.

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EXPLANATION OF PLATE

Fig. 1.—*Coxiella gilesi* (Angas), x 10; protoconch, x 37.
Fig. 2.—*Chara* sp. 1, oogonium, x 35.
Fig. 3.—*Chara* sp. 2 (?), oogonium, x 35.
Fig. 4.—*Chara* sp. 3 (?), oogonium, x 40.
Fig. 5.—*Pontocypris attenuata* Brady, adult left valve without spines, x 65.
Fig. 6.—*Pontocypris attenuata* Brady, juvenile left valve with anterior and posterior spines, x 65.
Fig. 7.—*Cypris* sp., both valves, lateral view, x 80.
Fig. 8.—*Cypris* sp., left valve, x 85.
Fig. 9.—(?) *Elphidium advenum* (Cushman), x 110.
Fig. 10.—(?) *Nonion scapha* (Fichtel & Moll), x 85.
Fig. 11.—*Cibicides refulgens* Montfort, apertural view, x 180.
Fig. 12.—*Cibicides refulgens* Montfort, dorsal view, x 180.
Fig. 13.—*Rotalia beccarii* (Linné) var. *tepida* Cushman, extreme form, dorsal view, x 80.
Fig. 14.—*Rotalia beccarii* (Linné) var. *tepida* Cushman, extreme form, ventral view, x 80.
Fig. 15.—*Rotalia beccarii* (Linné) var. *tepida* Cushman, calcified specimen, typical of Lake Eyre sediments, x 80.